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a transparent spot in the test and wandered inward or become altogether effaced. In the Cambrian trilobites, the tubercle, for the most part, is also absent; the median eye from the present evidence, being still in its most primitive form of one or two transparent spots of the test.

It is a distinct fact pointing to a visual function of the median tubercle that the genera usually considered as blind because of reduced or absent lateral eyes, are apt to show these median eye tubercles most distinctly, as notably *Cryptolithus*, *Trinucleus*, *Dionide*, *Dindymene*, and also *Agnostus*, *Microdiscus* and *Ampyx*, while on the other hand the genera, *Phacops* and *Dalmanites* with their highly developed lateral eyes, show the least trace of the median eye. Its constant presence in a great number of genera is further evidence of its important function; and finally the fact that all lower crustaceans typically possess the median or parietal eye and that for that reason zoologists of standing have already simply assumed the presence of this organ in the trilobites, makes it a reasonable inference that these primitive early crustaceans should have also possessed the median eye, in at least some stages of their evolution, and that is what the writer hopes to have demonstrated.

A fuller account of this investigation is being printed in a New York State Museum Bulletin.

THE NATURE OF MECHANICAL STIMULATION

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Received by the Academy, March 13, 1916

The effects of certain kinds of stimuli can be referred directly to chemical changes which they produce in the protoplasm, but there are other kinds which appear to operate by physical means only. In the latter category are such stimuli as contact, mechanical shock and gravitation. While their action appears at first sight to be purely mechanical, they are able to produce effects so much like those of chemical stimuli that it appears probable that in every case their action must involve chemical changes.

The chief difficulty which confronts a theory of mechanical stimulation appears to be this, How can purely physical alterations in the protoplasm give rise to chemical changes? It would seem that a satisfactory solution of this problem might serve to bring all kinds of stimulation under a common point of view, by showing that a stimulus acts in every case by the production of chemical reactions.

An answer to this question is suggested by some observations of the writer. These were originally made on the cells of the marine alga *Griffithsia Bornetiana*. A cell of this alga is shown in figure 1. Within the cell wall (a) is a thin layer of protoplasm (b) which encloses the large central vacuole (e). The protoplasmic layer includes numerous chromatophores (c). The latter contain chlorophyll and a red pigment (phycoerythrin) which is soluble in water. Under normal conditions the surface of the chromatophore is impermeable to the red pigment, which is thus confined to the chromatophore and prevented from escaping into the surrounding protoplasm or into the vacuole.

The writer has observed when one of the larger cells is placed under the microscope (without a cover glass) and touched near one end (with a needle or a glass rod or a splinter of wood) a change occurs in the chromatophores directly beneath the spot which is touched. The sur-

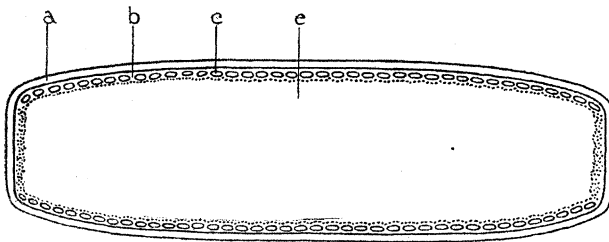


FIG. 1.—A CELL OF *GRIFFITHSIA BORNETIANA* (IN OPTICAL SECTION). a, CELL WALL; b, PROTOPLASM; c, CHROMATOPHORE CONTAINING CHLOROPHYLL AND A RED PIGMENT (PHYCOERYTHRIN) WHICH IS SOLUBLE IN WATER; e, VACUOLE FILLED WITH CELL SAP. (DIAGRAMMATIC.)

faces of the chromatophores in this region become permeable to the red pigment, which begins to diffuse out into the surrounding protoplasm.

This change begins soon after the cell is touched. As the red pigment diffuses through the protoplasm it soon reaches neighboring chromatophores and it may then be seen that their surfaces also become permeable and their pigment begins to diffuse out. In this way a wave—which may be compared to a wave of stimulation—progresses along the cell until the opposite end is reached.

The rate of propagation of this wave corresponds to that of the diffusion of the pigment. It would seem that at the point where the cell is touched, pigment, and probably other substances, are set free, diffuse out and set up secondary changes as they progress. These changes are doubtless chemical in nature.

The important question then arises, How does the contact initiate the outward diffusion of the pigment or other substances?

It seems to the writer that this may be due to a mechanical rupture of the surface layer of the chromatophore which is either not repaired at all or only very slowly. Many cases are now known in which the

surface layers of protoplasmic structures behave in this way.* If therefore, such structures exist within the cell, it is evident that any deformation of the protoplasm which is sufficient to rupture their surface layers will permit their contents to diffuse out into the surrounding protoplasm. A great variety of cellular structures (plastids, vacuoles, 'microsomes,' inclusions, etc.), possess surface layers of great delicacy and it is easy to see how some of these may be ruptured by even the slightest mechanical disturbance.

It is therefore evident that deformation of the protoplasm may rupture the surface layers of certain protoplasmic structures and cause their contents to diffuse out. If the substances which thus diffuse out meet other substances from which they were separated by the semipermeable surface layer before it was ruptured it is easy to see how reactions may be set up which in certain cells may bring about the responses characteristic of mechanical stimulation. The occurrence of such reactions seems probable, since many cases are known where substances in close juxtaposition are prevented from reacting by the presence of such semipermeable layers; but when these layers are destroyed (by crushing the cells) the reaction at once takes place.

If these processes occur it is evident that purely physical alterations in the protoplasm can give rise to chemical changes. Responses to contact and mechanical stimuli may thus be explained; and since gravitational stimuli involve deformation of the protoplasm we may extend this conception to geotropism.

In this conception of mechanical stimulation the essential things are (1) substances which are more or less completely prevented from reacting by semipermeable surfaces, (2) a deformation of the protoplasm sufficient to produce in some of these surfaces a rupture which is not at once repaired, (3) a resulting reaction which produces the characteristic response to the stimulus.

* In many cases rupture of the plasma membrane causes the protoplasm to disintegrate and mix with the surrounding medium. In other cases the surface layer is at once reconstituted.